Societal Life Cycle Assessment (Subject Editor: David Hunkeler)

Societal LCA Methodology and Case Study *

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Abstract

Goal, Scope and Background. Societal assessment is advocated as one of the three pillars in the evaluation of, and movement toward, sustainability. As is the case with the well established LCA, and the emerging LCC, societal life cycle assessment should be developed in such as way as to permit *relative product comparisons*, rather than absolute analyses. The development of societal life cycle assessment is in its infancy, and important concepts require clarification including the handling of the more than two hundred social indicators. Therefore, any societal life cycle assessment methodology must explain why it is midpoint- or endpoint-based as well as its reasons to be complimentary with, or included within, life cycle assessment.

Methods. A *geographically specific midpoint based societal life cycle assessment methodology, which employs labour hours as an intermediate variable* in the calculation has been developed and evaluated against an existing LCA comparing two detergents. The methodology is based on using an existing life cycle inventory and, therefore, has identical system boundaries and functional units to LCA. The societal life cycle assessment methodology, much like LCA, passes from inventory, through characterisation factors, to provide an ultimate result. In analogy to economics and cost estimation, societal life cycle assessment combines, into its statistics, both data as well as estimates, some of which are correlated to elements of the LCI. It focuses on the work hours required to meet basic needs.

Results. The societal life cycle assessment of an appended case study indicates that Detergent 2 generates, relative Detergent 1, approximately 20% less employment in Russia, 35% less in France, and approximately five times more in Canada and South Africa, the latter derived from its higher aluminium content. There is essentially no difference in the employment in the use country (Switzerland) nor in Morocco, where some of the waste disposal was assumed to take place.

Discussion. Given that housing is more affordable, in terms of shelter units per labour hour, in South Africa, compared to Europe, it is, therefore, of no surprise that Detergent 2 provides a societal benefit in terms of housing. Detergent 2 does, however, result in dematerialization, in that its environmental impact is lower (LCI). Therefore, as less resources are employed and labour required, in extraction, production and transport, the societal benefits in health care, education and necessities, a grouped variable, are lower for Detergent 2. This is despite the employment shift away from Europe and to less 'developed' regions.

Conclusions. The assessment of societal impacts involves several hundred specific indicators. Therefore, aggregation is, if not impossible, at least heavily value laden and, therefore, not recommended. The impact of a societal action, derived from a product purchase or otherwise, is also highly local. Given this, societal life cycle assessment, carried through to the midpoints, and based on an existing LCI, has been developed as a methodology. The results, for an existing LCA-detergent case, illustrate that societal life cycle assessment provides a means to investigate how policy and policy makers can be linked to sustainable development. The sensitivity analyses also clarify the decisions in regards to product improvement.

Recommendations and Perspectives. The goal of societal life cycle assessment is not to make decisions, but rather to point out tradeoffs to decision- or policy-makers. This case, and the methodology that it is based on, permit such a comparison. Substituting Detergent 2 for Detergent 1 reduces resource use at the expense of an increase in atmospheric and terrestrial emissions. Access to housing is improved, though at the expense of education, health care and necessities. As a recommendation, one would look at the fact that the majority of indicators are superior for Detergent 2 relative to Detergent 1and seek to improve the aqueous emissions in Detergent 2 via a change in the formulation. An energy or fossil fuel substitution at the site of production could also improve the societal benefits in terms of education and health care.

While societal life cycle assessment remains in its infancy, a methodology does exist. The field can, therefore, be viewed in a similar way to LCA in the early 1990s, with a need to validate, consolidate and, ultimately, built toward a standard. The contribution is aimed at contributing to such a discussion and therefore proposes that a societal life cycle assessment be LCI-derived, geographically specific, based on mid-points, and use employment as an intermediate variable.

Keywords: Decision-making; detergents; life cycle costing (LCC); life cycle inventory (LCI); policy-making; social impacts; social indicators; societal assessment; sustainability

Introduction

Societal assessment is viewed by some authors (Klöpffer 2006) and organisations as a complement to Life Cycle Assessment and Environmental Life Cycle Costing (Hunkeler et al. 2006) as a third component of measuring sustainability development. That is not to say that there is a consensus as to how to integrate, let alone calculate, comparative social effects of products (Hunkeler and Rebitzer 2005). The field of sustainability assessment is, indeed, new, and includes contributions related to including social aspects within LCA (Weidema 2005, Weidema 2006). Clearly, as the methodology of societal assessment evolves approaches must be distinguished wherein societal assessment is *combined-within* or *combined-with* other methods. The earliest example of the former is the work by O'Brien and Clift in 1996. An additional means for categorisation relates to the issue of mid-point versus end-point calculations. As the number of

* The Methodology is presented in the main paper and the Case Study in the Appendix.

social indicators is large, at over two hundred, the issues of thresholds and screening must be addressed for any mid-point based procedure. Very recent work on societal assessment, as well as social indicators, includes the contributions of Dryer et al., Labuschagne and Brent, Weidema, Norris and Klöpffer, all published in 2006.

The present paper is a preliminary attempt to elaborate a methodology for *mid-point based societal life cycle assessment* for *comparative product assertions*. From the outset, the goal is to render this procedure compatible with LCA and Environmental-LCC, and, is therefore, based on the same functional unit and system boundaries as these methods (Rebitzer and Hunkeler 2003). This is demonstrated using a case study evaluating two detergents for which the life-cycle inventory has been previously published, and extensively cited.

The specific goals of this publication are to demonstrate that societal life cycle assessment can be:

- based on a precise methodology
- linked to inventory data
- calculated via characterisation factors similar to those in LCA
- linked to databases which estimate the geographical distribution of a product's burden

Societal life cycle assessment will, it seems, differ from LCA in one important regard. In LCA impacts are geographically homogenised, with continental or global averages often assumed. We will attempt to illustrate, herein, that societal life cycle assessment is linked, at the minimum in part, to how a product's life cycle effects regional employment. As key societal indicators, such as housing, health care, education and necessities are very regionally dependent, societal life cycle assessment will require an additional set of product specifications throughout the life cycle. Specifically, and as will be shown, comparative mid-point based societal life cycle assessment must specify the geographical distribution of labour in the extraction, transport, use and disposal stages.

This publication is intended as a preliminary model for societal life cycle assessment. It is written as a specific document to provide a base for criticism as well as a means to provoke the advancement of the procedure. In doing so, we attempt to set societal life cycle assessment at a point roughly equivalent to LCA in the early 1990s. A case study presented in the appendix will, to the extent possible, use published data, with some estimates provided. As will be demonstrated, societal life cycle assessment will require the establishment of some unique, though not difficult to obtain, regionally-specific databases.

1 Methodology

A procedure for societal life cycle assessment is proposed derived from life cycle inventory data. As such, the analyses have identical system boundaries and functional units. The methodology will be explained, both qualitatively and mathematically, step-by-step from the Societal LCI, through the characterisation factors, which them selves depend on the geographical distribution of employment. Overall, the Societal LCA proposed herein comprises five principal steps which quite resemble environmental LCA:

1. A geographically specific **life cycle inventory** is established for each unit process.
2. The **employment hours for each unit process** are calculated in each of the relevant geographical regions.
3. An overall **employment table** is calculated based on the LCI and employment distribution between regions an unit processes by combining the data in Points 1 and 2.
4. The **regional characterisation factors** are estimated.
5. The **characterisation result**, which is, by definition, the Societal LCA, is calculated from the geographical employment data and characterisation factors.

The method developed herein focuses on the work hours required to meet basic needs, It is important to label this type of societal life cycle assessment as an LCI-based concept wherein labour hours are used as the single variable in the calculation, much as a monetary unit, such as Euro is applied in Environmental Life Cycle Costing. Therefore, the societal life cycle assessment proposed is micro-economic in nature, in that it examines the effect of product substitution on the state of average workers in countries where the product life cycle has an effect. It differs from the, more macroeconomic *social* assessment, in that the effect of government programs is covered explicitly in social assessment and implicitly, via overhead and taxes, in societal life cycle assessment.

2 Calculation Procedure

Societal life cycle assessment, as presented herein, assumes that an LCI is available or will be obtained as part of the analysis. It makes the critical assumption that the individual unit processes within the LCI can be decomposed into regional, or often national, labour statistics, and, with these, some of which are calculated via correlations, as is also the case in estimation fields, characterisation factors are calculated. These characterisation factors are obtained by transforming the labour hours via general, case-independent, statistics. As Societal life cycle assessment applies the same system boundaries and functional unit as LCA, the unit process concept is also relevant. However, whereas in LCA the process tree is built up from connected unit processes with inputs (e.g. raw materials, energy and water) and outputs (e.g. intermediate products, emissions into air, water , soil, and co-products) in Societal life cycle assessment working hours are the relevant input. Furthermore, although employment hours have the advantage that they can be aggregated, one requires the employment hours per inventory element, per stage and per geographic region as will be shown in Sections 2.2 and 3.2. Total life cycle employment, if non-transparent, would not be a reasonable proxy.

As a qualitative example, the elements from the LCI, such as fossil fuel, electricity, as well as air and water-based emissions, to name just a few, are converted into labour hours. This conversion takes an element, such as rolled aluminium sheet, to use an example, and examines the hours required for extraction, transport to the production site, production, transport to the consumer, use and ultimate disposal. Some of these labour hours must, themselves, be divided between countries (e.g. if the Al source is in two countries). Further, the production and use are likely to be in different regions. From this newly based set of 'employment-inventory' tables one can

transform these hours into the ability to acquire societal necessities, such as housing, education and health care, by correlating the time available, in a geographic region, with the time required to acquire, marginally, one unit of, for example, health care. Ultimately, one tabulates, for each product examined, the ability to acquire societal necessities, across all countries (i.e. re-aggregating geographically) and the products are compared via their ability to, again marginally, contribute to fulfilling the various societal metrics.

It is recommended that employment be estimated from data on individual unit process since such information is transparent. If one examines, as an example, production of aluminium ingot, the capacity of a given site and its employment are known from the financial statements of the firm. Therefore, the employment (labour hours) per functional unit of product (aluminium) can be unambiguously calculated. Of course, the issue of co-allocation, so common in LCA, will be equally present in Societal Life Cycle Assessment. However, both LCA and the field of managerial (cost) accounting proposed standards for co-allocation and therefore the uncertainty in employment per unit of product is not anticipated to be very large. In similar ways as has been described for production the employment linked with upstream, transport and downstream unit processes would be estimated.

The methodology for societal life cycle assessment will be presented, first mathematically, then via a case study in the appendix.

2.1 Life cycle inventory

For a given product, the vector of the life cycle inventory is **I**, where $\mathbf{I}_i$ is the inventory of the **ith** category. These would be typical elements such as fossil fuel, electricity, both of which relate to energy, as well as resource-based inventories, emissions to air and water, and waste, as examples. We will, then, let $\mathbf{I}_i^1$, $\mathbf{I}_i^2$ and $\mathbf{I}_i^n$ bet the vector of LCIs for the first, second and up to nth product compared. Therefore, as could be expected, the LCI, for all products, is an i x n matrix ($\mathbf{I}_{in}$), where i is the inventory element and **n** is the number of alternative products compared. Though the use of vectors and matrices is uncommon in LCA parlance, it is not unprecedented (Heijungs 1997, 2001, Heijungs and Suh 2002). In more colloquial jargon, the $\mathbf{I}_i$ 'vector' is a column of a spreadsheet and the $\mathbf{I}_{in}$ 'matrix' is spreadsheet with n products tabulated in n columns over i rows of inventory elements.

2.2 Calculation of the Matrix of Employment Hours

As the societal life cycle assessment proposed herein passes through an intermediate calculation based on geographically dependent employment hours, a means to transform inventory into work time is required. The matrix of employment hours, per inventory element, is the $\mathbf{E}_{ij}$, where **i** is defined, as above, as an inventory element, and **j** is the employment in a given life cycle stage (e.g. extraction, production, etc.). As an example, E_{11} could be the employment hours in the extraction of fossil fuels, while E_{12} would be the employment hours in production linked with fossil fuels. E_{21} could the employment hours in the 'extraction' of energy and E_{42} might be the employment in the production of water based emissions, such as COD. Clearly, some inventory elements will cause employment in certain life-cycle stages, though not all, hence E_{ij} will be a relatively sparse matrix. The concept of life cycle working time, provided now in some databases, could be useful should it permit the distinction of labour for given unit processes and for specific regions.

The transformation of an LCI into employment could be considered as a monetisation of an environmental LCI though it is not intended, per se, as such. Rather the transformation of a non-regionally specific LCI into a regionally specific one is the underlying driver. Labour hours offer other advantages, as will be discussed herein including, as midpoints, the additivity between categories. Moreover, economists and sociologists alike use employment and its distribution as factors in establishing macro-indicators, both for the environment and economy providing a precedent for use in sustainability calculations.

2.2.1 Geographical employment factors across life cycle stages

The E_{ij} employment matrix must be developed for a baseline geographical region (e.g. Germany). Should one wish to make labour calculations in various regions, one would be required to either have an E_{ij} matrix for each region (one should note that the E-matrix is product independent) or provide a means of transforming the E-matrix. The author prefers the latter, in analogy to the methodologies employed in cost estimation. Therefore, we generalise the E-matrix to account for geographical variations as follows. $\mathbf{E}_{ij}^G$, is defined as the matrix of employment hours in a given geographical region '**G**'. We will then define a matrix, $\boldsymbol{\alpha}_i^G$, as a correlation of equivalent employment hours between regions, which is again, product independent and is macroeconomic in nature. The matrix $\boldsymbol{\alpha}_i^G$ expresses the ratio of employment hours between regions for a given inventory element. It is normalised relative to the base-case geographical region. As an example, α_1^{Russia} has a value of 1.5 if, in Russia, 150% of the labour hours are required to extract fossil fuel relative to Germany. Similarly, α_1^{France} may be 1.20 as France has a shorter work week and fossil fuel extraction is time dependent. However, for a different inventory element, the values may change. Therefore, α_2^{France} may be less than in Germany as the French energy production may be labour efficient relative to its cross-border counterpart.

One can calculate the employment hours in each geographical region via Eq. (1):

$$E_{ij}^G = E_{ij} \times \boldsymbol{\alpha}_i^G \tag{1}$$

Where one should recall that E_{ij} relates to the base country (e.g. Germany).

2.2.2 Geographical employment-estimation of emission- and transport-based data

It is likely that countries, and regions, will have better access to energy data than for other life cycle inventories which many not enter into the national statistics. Therefore, a matrix could be defined which permits the estimation of employment hours in remediation per region, from energy

data. If such a matrix were employed it would relate the hours needed in remediation, locally, to clean up damage from $C0_2$, COD, heavy metals and solid waste, to name just a few. Therefore, it is regionally dependent and can be expressed as β_i^G, where i is, as always, the inventory element and G the geographic region. As an example, we may estimate that it requires 0.3 hours today for CO_2 remediation, in Germany *per* each unit of energy while 2 hours for solid waste management (β_1^D and β_4^D respectively). If solid waste cleanup requires 4 hours (per hour of energy) in Morocco, then β_4^M would have a value of 4. It should be underlined that the β-matrix may not be required if sufficient data can be calculated from Eq. (1). The β-matrix is a supplemental estimation tool should data be missing from the α-matrix. It is also critical to note that the hours related to emissions are those which occur at present. The method is not seeking to estimate the employment required to actually remediate the effect, or example, of $C0_2$. Neither the timing, nor the magnitude, of such remediation cannot be ascertained with any certainty. Further, such impacts are better left to LCA. What societal life cycle assessment must tabulate is the current employment hours linked with the monitoring (either in firms or publicly) of the ultimate effects of $C0_2$ emissions, as well as any present attempts to reduce this via treatment (e.g. sequestration in the case of large point sources).

The data in the α-matrix for the life cycle transport stage (both to the producer, to the customer and to the ultimate disposal) may have to be estimated rather than input from national statistics. The case study, in the appendix, will provide an example of such an estimation, though it is not an intrinsic part of the methodology and is applied, as was the case for emissions, only if data is missing.

2.3 Overall employment table

The overall matrix of employment hours, for a given inventory-region (**k**) and a life cycle stage (**j**) is given by the $\mathbf{H_{kj}}$ matrix. The index k represents an inventory *in a given region* (e.g. fossil fuels in Germany, fossil fuels in Russia). The H-matrix is calculated from the product of the LCI and the Employment matrices:

$$\mathbf{H_{kj}} = \mathbf{I_{in}} \times \mathbf{E_{ij}}^G \tag{2}$$

Each product alternative will have its own H-matrix, therefore, $\mathbf{H_{kj}}^1$ would represent all employment hours, for a given inventory element, region and life cycle stage associated with, for example, Detergent 1. Similarly, $\mathbf{H_{kj}}^2$ would represent the entire employment hour distribution associated with Detergent 2. The H-matrix, with 'H' designating hours, is the key in calculating societal life cycle assessment by transforming an LCI database. From the H-matrix, as will be shown, the societal impact can be determined using a characterisation table.

2.3.1 Employment summary

One convenience, as well as important advantage, associated with tabulating hours of work is that it is a unit that can be aggregated. Therefore, *one could summarize, across impact categories and across life cycle stages, the total number of employment hours in a given region*. As an example, one could add the labour hours for fossil fuel across all life cycle stages, in Germany, with those for electricity, aluminium and emissions, to come up with a total number of employment hours associated with a given product in Germany. This could be calculated for each product alternative (n) and each region (G) as:

$$\mathbf{R}^{G,n} = \sum \mathbf{H_{kn}} \tag{3}$$

where Eq. (3) is, clearly, summed across all impacts (i) and all stages (j) for a given region (G) and product alternative (n). It yields the R-matrix which is the total employment in a region for a given functional unit. As an example, Detergent 1 may result in 5.9 hours of employment, across the life cycle, in Germany, 1.9 hours in Russia, 1 hour in France and 0.26 hours in Canada. Similarly, Detergent 2 may result in 4.13 hours in Germany, 1.57 hours in Russia, 0,75 hours in France and 1.3 hours in Canada, as examples. One can already begin, via the R-matrix, to appreciate the societal differences between the products being compared. This shows that the LCI to be used in societal life cycle assessment has to be much more detailed than the LCI usually used in LCA. However, an *LCI used for social LCA can also be used for a better, regionally resolved LCIA*, though one should recognize that there will be more problems with data collection and especially with the use of generic data.

2.4 Characterisation factors and table

For societal life cycle assessment, we define $\mathbf{C_A}^G$ as the *characterisation factor* for a given societal impact category '**A**' (e.g. housing, health care or education) in a given region. The overall 'C-matrix' of such characterisation factors is the *characterisation table*. As an example, it may require 20,000 hours of an average labourer to work to purchase housing in Germany (C_1^D), compared to 50,000 hours in Russia (C_1^R). Similarly, the average German may require 600 hours of work to afford health care, including taxes of course (C_2^D), compared to 3000 in Russia (C_2^R) and 400 in France (C_2^F).

Though the characterisation factors and table are completely different, than in LCIA, the use of such tables, linked to transformed inventory data, is similar in societal life cycle assessment and life cycle assessment, as will be demonstrated in the case study.

2.5 Calculation of characterisation results

The result of the societal life cycle assessment, i.e. the characterisation result, is a set of societal impact categories (A) across various regions (G) and for various products (n). These could be viewed as sub-divided midpoints, with the summing over all geographic regions the total value of the midpoint. In the example to be presented in the appendix four midpoint categories are applied. This is for illustrative purposes only so as to reveal the full details of the methodology. It would be quite likely that for a Societal LCA, similar to an LCA, that the total number of midpoints above a reasonable threshold would be over ten. Therefore, $\mathbf{S_A}^{G,1}$ is a matrix for a given product and is the conclusion of the societal life cycle assessment. One could show, for example, that Detergent 1 contributes 0.00074 housing units in Germany ($S_1^{D,1}$) and 0.000010 housing units in Russia ($S_1^{R,1}$), whereas it provide 0.00246 health care units in Germany

($S_2^{D,1}$), as examples. In contrast, Detergent 2 may provide 0.00052 housing units in Germany ($S_1^{D,2}$), 0.000008 housing units in Russia ($S_1^{R,2}$) and 0.00172 health care units in Germany ($S_2^{D,2}$). The S-matrix is calculated as follows for each product (n, varying between 1 and n):

$$\mathbf{S}_A^{G,1} = (\mathbf{R}^{G,1} \cdot \mathbf{W}_A) / \mathbf{C}_A^G \tag{4}$$

Where $\mathbf{W}_A$ is an arbitrary set of weighting factors that distribute the total employment summary across the societal impacts. As an example, if Detergent 1 lead to 13.13 hours of employment in and there were four societal impact categories (an extremely low number for illustration only), then one could imagine that an egalitarian would allocate one-fourth to each impact. Specifically, the egalitarian value system would give W_1, W_2, W_3 and W_4 values of 0.25 (equal weighting for housing, health care, education and necessities). The value system should not, in the author's opinion, be part of the methodology and the calculations should be possible for any set of published weights. A result should, therefore, be coupled with the underlining assumptions and presented as such.

The S-matrix is the result of the societal life cycle assessment. One would likely not distinguish, at the end of the assessment, between countries and one would, therefore, likely aggregate the mid-points (i.e. each societal impact 'A') across regions:

$$\mathbf{S}_A^1 = \Sigma\, \mathbf{S}_A^{G,1} \tag{5}$$

The S-matrix may note, for example, that Detergent 1 provides 0.001 housing units, 0.0038 health care units, 0.009 education units and 0.043 necessity units. Detergent 2 provides 109%, 90%, 90% and 93% of the societal impact (less being less favourable). As was expressed at the outset, this version of societal life cycle assessment is midpoint based, hence there is no attempt to calculate an overall Socio Indicator. It would certainly be possible to further aggregate and a minor mathematical step for which all the data are available with the exception of weighting factors which would be contested as value laden (Hunkeler 1999) and not recommended.

3 Discussion

3.1 A Critique of the proposed method for societal life cycle assessment

The methodology for societal life cycle assessment, which has been presented, is based on the transformation of a life cycle inventory into labour units. This transformation specifies the geographic region of the impact, or the labour, the latter of which can be either direct (e.g. in extraction, transport or production) or indirect (e.g. in remediation or controlling). This transformation from LCI to labour hours is a key feature of the method. Such a transformation, or one which is similar in that it provides a societal inventory on common units, is necessary if one wishes to compare products. As the number of societal (microeconomic) and social (macroeconomic) indicators approaches three hundred, and societal and economic impacts are linked to their geographic region, much more so than environmental ones, the question of establishing a societal inventory is daunting. However, we have the product-based inventories from an environmental perspective and these are often of very good quality, for which the sources are transparent and the data quality estimated. Furthermore, if sustainability is to have three pillars (Klöpffer 2003, Klöpffer 2006) which have the same functional unit and system boundaries, and the environmental arm of this assessment (LCA) is the most advanced, it seems logical to base societal life cycle assessment on LCI.

The advantages of using labour as a means to transform LCI data are that it is verifiable, and, as an intermediate means to calculate, additive. Further, the use of any intermediate, additive, variable avoids the problem of having too many midpoints which may require aggregation. In societal life cycle assessment the probability of obtaining a consensus on the weighting of the vast number of midpoints is unlikely. Another advantage of using labour statistics is that they can be estimated, and significant work has been carried out in correlating labour hours to various technical tasks, including production. Therefore, the LCI-to-labour hour transformation requires database development for societal life cycle assessment, but these are, rather, correlations. Without an LCI transformation, we force ourselves to create a societal database from scratch, and this risks not only not being done for a decade but also double counting and incompatibility of the two approaches.

A labour driven societal life cycle assessment implies that the geographic distribution of employment or working hours, as one compares two products, will influence the outcome. It also indicates that changes in technology which dematerialise *and* increase the profit margin (and hence reduce labour in particular in poorer regions) will have an adverse societal impact. The use of labour statistics in societal life cycle assessment, therefore, implies that societal benefit is linked to wealth. Idealistically one could contest this and for this reason wealth is defined herein not as a personal attribute (i.e. direct income and assets) but rather as a combination of the direct and indirect, where the latter includes the programs provided to an individual, family or organisation by the state and its employer. Perhaps this would still perturb some philosophers. However, how could a state pay for health care, or partly subsidise education, without tax revenue, and how can housing and necessities be accessed without a salary or equivalent income?

Overall, and after much reflection, we have developed a societal life cycle assessment methodology which is based on LCI, does use labour statistics as an intermediate variable, is geographically specific and ends with midpoint assessments. The author feels that, for the reasons elaborated above, this is the most appropriate compliment to LCA as a pillar of sustainability.

4 Conclusions

The assessment of societal impacts involves several hundred specific indicators. Therefore, aggregation is, if not impossible at least heavily value laden and, therefore, not recommended. The impact of a societal action, derived from a product purchase or otherwise, is also highly local. Given these two constraints, a *geographically specific midpoint based-societal life cycle assessment methodology* is the only which can be considered to compliment LCA and LCC as pillars of sustainability. Furthermore, if societal life cycle assessment is to

base itself, as seems generally recommended, on the same system boundary, functional unit, and inventory as LCA, a common basis will be required. More specifically, if one employs the life cycle inventory in societal life cycle assessment, one will have to transform the LCI units into a common basis. Labour hours are one such basis. Ideologically, one could object to the implicit link between societal well-being and employment or the distribution, both geographic and within a population, of wealth. However, reality illustrates that the broadening Lorenz curve (gap between wealthiest and poorest people) does provoke social difficulties. A methodology for a societal life cycle assessment tool has been presented, and demonstrated on an existing case study. The results illustrate that societal life cycle assessment provides a means to investigate how policy and policy makers can be linked to sustainable development. The sensitivity analyses also clarify the decisions in regards to product improvement. Overall, an *LCI-derived, geographically specific midpoint based societal life cycle assessment methodology, which employs labour hours as an intermediate variable* in the calculation can, indeed, be employed for societal life cycle assessment.

5 Recommendations

The goal of societal life cycle assessment is not to make decisions, but rather to point out tradeoffs to decision- or policy-makers. This case, and the methodology that it is based on, permit such a comparison. **Fig. 1** summarises the environmental (LCIA) and societal life cycle assessments for the two detergents considered in the appendix. Substituting Detergent 2 for Detergent 1 reduces resource use at the expense of an increase in atmospheric and terrestrial emissions, though aqueous emissions are reduced significantly. The fact that this particular societal life cycle assessment does not result in black and white answers is not, per se, negative. There are, even when one combines only the environment and economy, few low hanging fruit. When the third axis of sustainability is added, choices and balance become important. More so than anything else, the link between sustainability and policy is underlined by this methodology.

As a recommendation, one would look at the fact that the majority of indicators are better for Detergent 2 relative to Detergent 1 (i.e. less than 100% in Fig. 1) and seek to improve the aqueous emissions in Detergent 2 via a change in the formulation. An energy or fossil fuel substitution at the site of production could also improve the societal benefits in terms of education and health care. The overall recommendation could be to examine technological aspects linked with the production and material sourcing for the formulation to determine if a hybrid of the benefits of Detergent 1 and 2 could not be possible.

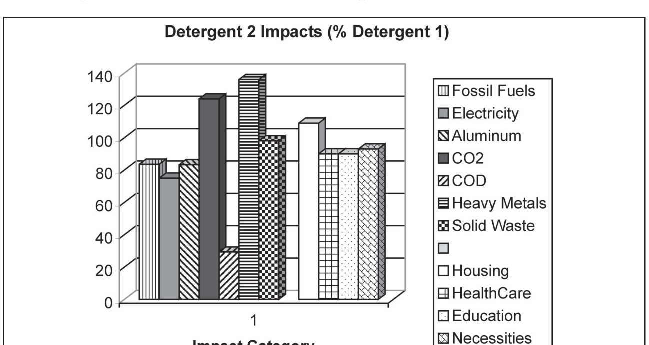

Fig. 1: Ratio of the impact assessment and societal life cycle assessment, for each variable considered in the case. All data are expressed as the calculated result of Detergent 2, relative to that for Detergent 1

6 Perspectives

Should we seek to monitor and move towards sustainability the societal life cycle assessments of products, through their life cycle, are required as compliments to LCA and Environmental Life Cycle Costing. While the advantages of having all three methods complimentary and based on the same functional unit and system boundary are clear, other issues will require resolution. Should we, for example, restrict societal life cycle assessment to mid-points with the risk of having a large number of indicators? Will the need for societal life cycle assessment to be geographically based require re-working of some existing life cycle inventories? Will the use of labour as a variable which can be integrated across unit processes, and geographically, be accepted, if not by scientists by politicians? The dialogue which is beginning on societal, and also social, assessment should, over the coming years, clarify a target for the method, in responding to these, and other, questions. Debate should also ensure that the means to obtain these objectives is the most expedient. Further, given the example of LCA, societal life cycle assessment should be able to resolve these issues over a shorter time frame than its predecessor.

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Appendix

A Case Study Comparing two Detergents

The methodology for societal life cycle assessment, developed in the preceding article, will be presented for an existing case evaluating two detergents (Baumann 2004). For sake of demonstration, the analysis that will follow is highly 'screened' in nature, though without any complication a complete analysis could have been carried out as the data are available. The calculations in the case are presented in the 5-step format proposed in the present Societal LCA publication.

A) 5-Step Format

Step 1: Life cycle inventory

Table 1 is an extract of Baumann and Tillman's Life Cycle Inventory data for two detergents (Baumann 2004). Table 1, therefore, represents the $\mathbf{I}_{in}$ matrix of various inventory elements (i) and products (n), where in this case n is a vector of two corresponding to the two detergents being evaluated. As the case is an existing one, no additional comment will be provided regarding the inventory data. The functional unit is 1 kg.

Step 2: Effect on employment

A basis of the societal life cycle assessment method presented herein is its evaluation of the employment hours linked with each unit process and inventory element, and for each product. This requires one to know, unlike LCA, where the unit process occurred. **Table 2**, therefore, represents, for the extract of inventories in the $\mathbf{I}_{in}$ matrix, a breakdown of each element, over the stage in which it occurred, expressed in person-hours of labour per LC inventory element. Therefore, one can see that the extraction of fossil fuels, relative to the functional unit in LCA, requires 0.086 person hours of employment, whereas 0.24 hours of labour are required in the monitoring of the generation of atmospheric admissions. As this labour is related to overhead effects, largely in the public sector and linked to monitoring and permitting, it is grouped under production as such organisations generally focus on the producer of the emissions. Table 2, which corresponds to the $\mathbf{E}_{ij}$ matrix with 'i' the vector of LC inventory elements and 'j' the vector of LC Stages, is quite sparse. Clearly, a goal of societal life cycle assessments must be to provide background inventory data such as one has for LCI and the completion of generic versions of Table 2, for various unit processes, would correspond to this task. Table 2 provides all the data required for the LCI extracts used in Table 1. It is calculated, as was discussed in Section 2, based on published microeconomic statistics. Specifically, data for individual firms (or from trade associations if available) which would extract, transport, or produce are analysed so as to divide the total production by the total labour and allocate a work-hour per unit. These data will vary geographically and data quality issues will apply, as they do in LCA. In converting a unit process to labour statistics, one also must ensure that a sufficiently good data sample (e.g. of firms or firms of a given size) is obtained. One must also distinguish the correct product type. As an example, the inventory for ingot-, rolled- and packaged aluminium differ remarkably. Finally, one must ensure, in re-calculating the microeconomic statistics, that the issue of co-allocation is responsibly handled.

Table 1: Extract of Life Cycle Inventory for two Detergents (I_{in} Matrix with 'i' the vector of LC Impacts and 'n' the product vector)

Impact Category	Sub Category	Value (Detergent 1)	Value (Detergent 2)
Energy	Fossil	11.6	9.7
	Electricity	4.4	3.3
Resources	Aluminium	0.048	0.096
Emissions: Air	CO_2	24.5	30.4
Emissions: Water	COD	4.1	1.2
	Heavy Metals	0.022	0.03
Waste	Solid	530	520
Functional unit 1 kg of Detergent: Baumann and Tillman (2004)			

Table 2: Employment per Unit of Life Cycle Inventory (E_{ij} Matrix with 'i' the vector of LC Impacts and 'j' the vector of LC Stages)

Impact Category	Sub Category	Employment in Extraction (h)	Employment in Production (h)
Energy	Fossil	0.0862	–
	Electricity	0.227	–
Resources	Aluminium	6.25	–
Emissions: Air	CO_2	–	–
Emissions: Water	COD	–	0.244
	Heavy Metals	–	–
Waste	Solid	0.001887	–

Table 3: Table of Geographic Employment Factors for Equivalent Goods (α_i^G Matrix with 'i' the vector of LC Inventory Elements and 'G' the vector of Geographical Regions)

Region: Region	Fossil Fuels	Energy
Russia: Germany	1.5	–
France: Germany	1.2	0.9
Canada	1.0	–
South Africa	1.3	–
Netherlands: Germany	1.0	–
Morocco: Germany	2.0	–

Employment correlations and estimation. One should, appropriately, note that employment linked to extraction, production or an emission, would differ from region to region. Therefore, rather than create societal life cycle assessment inventories which are geographically specific (see Table 2 for various unit processes, stages and regions) we prefer to correct a standardised $\mathbf{E}_{ij}$ matrix for geographical variation. This is akin to the standard process in the accounting linked to cost estimation. Therefore, **Table 3** represents the geographical variation in employment (the α_i^G matrix) expressed as a fraction of the base case, taken as Germany. Specifically, α_i^G matrix in Table 3 permits the calculation of employment hours in Russia, France, Canada, South Africa, The Netherlands and Morocco, where various LC unit processes occurred. As wage 'overhead'[1] rates differ not only from country to country but also from sector to sector, Table 3 is presented as a matrix as a function of the geographic region (G) as well as the LC inventory element (i). Overall, the $\mathbf{E}_{ij}^G$ matrix is a re-calculation (see Eq. 1) of the $\mathbf{E}_{ij}$ employment matrix accounting for geographical variations. The $\mathbf{E}_{ij}^G$ matrix will not be presented, per se, as it is integrated into the overall employment matrix ($\mathbf{H}_{kj}$) as will be explained below.

Similar to the α_i^G matrix, the β_i^G matrix tabulates the regional differences in employment linked to the monitoring and remediation of emissions. As was noted in the preceding paragraph, we prefer to establish a standardised $\mathbf{E}_{ij}$ matrix for a region (Germany) and correct it with a factor that accounts for regional differences. The β_i^G matrix of **Table 4** expresses emissions-based employment as a ratio of the energy used in the process. This is developed as such to provide a facile means to calculate unknown societal inventory data, again in analogy to cost estimation. It is assumed that the labour-hours linked with emissions, for certain cases, would be quite difficult to estimate though in the majority of examples, life cycle energy data would be available or more readily obtainable. Furthermore, the labour hours of emissions are those related to monitoring or remediation. The emission itself is treated in LCA. The β_i^G matrix is also quite sparse (as is the α_i^G matrix), reflecting the present, limited, state of societal life cycle assessment inventory. However, as will be seen in the following sections, it is sufficient to calculate assess the societal impacts of the two detergents in this screened example.

[1] Labour overhead is a means to express the employment hours required when comparing two, for example, geographic regions. Therefore, if in Russia 50% additional labour hours are required in extraction relative to in the Netherlands, Russia would have an overhead of 50% if the Netherlands was used as a base case.

Step 3: Employment calculations

The culmination of a mid-point, employment-hour, based societal life cycle assessment is the $\mathbf{H}_{kj}$ matrix, calculated using Eq. (2). These Employment Tables are shown for Detergent 1 in **Table 5** and for Detergent 2 in **Table 6**. It is essential to note how some of the entries in the $\mathbf{H}_{kj}$ matrix have been estimated and the following points illustrate key examples of the application of the α_i^G and β_i^G matrices :

- The fossil fuel for the detergents, which are produced in Germany, is obtained from Russia. Therefore, the 1.5 hours of labour related to fossil energy production in Table 5 is estimated from the 11.6 units from Table 1 (LCI) for fossil fuel, the 0.0862 hours of employment (in Germany, see Table 2) for fossil fuel extraction and the correction factor of 1.5 from Table 3. The latter is necessary as extraction in Russia consumes 150% of the labour as it does in the base geographical region of Germany. The product of these three values provides the labour hour in Table 5 (1.5 hours). Therefore, the utility of the α_i^G matrix is demonstrated.
- Even though the fossil fuel is extracted in Russia, it is transported partly using Russian and German means, and hence there is, respectively, 0.1 and 0.4 employment hours linked to the transport (see Table 5). The fossil fuel is, however, used only in Germany (site of production) and this accounts for 1 person hour of labour. These data are direct estimates, not relying on calculation.

Table 4: Emission and Employment Factors Per Geographic Region (β_i^G Matrix with 'i' the vector of LC Impacts and 'G' the vector of Geographic Region)

Country	Remediation Hours/Energy Unit			
	CO_2	COD	Heavy Metals	Solid Waste
Germany	0.3	1	0.001	2
Russia	–	–	–	–
France	–	–	–	–
Canada	–	–	–	–
South Africa	–	–	–	–
Netherlands	–	–	–	–
Morocco	–	–	–	4

Table 5: Employment Table for Detergent 1 (H_{kj} Matrix with 'k' the vector of Inventory-Regions and 'j' the vector of LC Stages)

Inventory Category	Sub Category	Geographic Location	Employment (Hours/Functional Unit)					Total Employment (h)
			Home Country	Transport to Producer	Production Country	Transport to User	Use Country	
Energy	Fossil	Germany	0	0.1	1	–	–	1.100
		Russia	1.5	0.4	0	–	–	1.900
		Total	1.5	0.5	1	0.2	0.5	3.700
	Electricity	Germany	0	0	1	–	–	1.000
		France	0.9	0.1	0	–	–	1.000
		Total	0.9	0.1	1	0.1	0.2	2.300
Resources	Aluminium	Canada	0.2	0.02	0.04	–	–	0.260
		South Africa	0.13	0.01	0.02	–	–	0.160
		Total	0.33	0.03	0.06	0.01	0.1	0.530
Emissions: Air	CO_2	Germany	0	0	0.3	0	0	0.300
Emissions: Water	COD	Germany	0	0	1	0	0	1.000
	Heavy Metals	Germany	0	0	0.001	–	–	0.001
		Netherlands	–	–	–	–	–	0.000
		Total	0	0	0.001	0	0	0.001
Waste	Solid	Germany	0	0	2	0.4	0.1	2.500
		Morocco	2	0.4	0	0	0.4	2.800
		Total	2	0.4	2	0.4	0.5	5.300
Grand Totals	–	–	4.730	1.030	5.361	0.710	1.300	13.131

Table 6: Employment Table for Detergent 2 (H_{kj} Matrix with 'k' the vector of Inventory-Regions and 'j' the vector of LC Stages)

Inventory Category	Sub Category	Geographic Location	Employment (Hours/Functional Unit)					Total Employment (h)
			Home Country	Transport to Producer	Production Country	Transport to User	Use Country	
Energy	Fossil	Germany	0	0	0.80			0.800
		Russia	1.25	0.32	0			1.574
		Total	1.25	0.32	0.80	0.16	0.4	2.934
	Electricity	Germany	0	0	0.7			0.700
		France	0.675	0.07	0			0.745
		Total	0.675	0.07	0.7	0.07	0.14	1.655
Resources	Aluminium	Canada	0.4	0.2	0.7			1.300
		South Africa	0.26	0.1	0.2			0.560
		Total	0.66	0.3	0.9	0.1	1	2.960
Emissions: Air	CO_2	Germany	0	0	0.24	0	0	0.240
Emissions: Water	COD	Germany	0	0	0.29	0	0	0.293
	Heavy Metals	Germany	0	0	0.0015			0.002
		Netherlands						0.000
		Total	0	0	0.0015	0	0	0.002
Waste	Solid	Germany	0	0	1.6	0.4	0.1	2.100
		Morocco	1.96	0.4	0	0	0.8	3.162
		Total	1.96	0.4	1.6	0.4	0.9	5.262
Grand Totals	–	–	4.552	1.090	4.534	0.730	2.440	13.346

Table 7: Employment Summary ($R^{G,n}$ Matrix with 'G' the vector of Geographic Regions and 'n' the Product vector)

Country	Hours Detergent 1	Hours Detergend 2
Germany	5.901	4.134
Russia	1.900	1.574
France	1.000	0.745
Canada	0.260	1.300
South Africa	0.160	0.560
Morocco	2.800	3.162
Switzerland	1.110	1.870
Totals	13.131	13.346

- The employment related to the *monitoring and regulation of emissions*[2] from production are, clearly, not known, even to the firm. They are, therefore, estimated from the $\boldsymbol{\beta}_i^G$ matrix, much as overhead is estimated in costing process equipment or plant installation. For a given number of labour hours of fossil fuel used in production (1.0), Table 4 (the $\boldsymbol{\beta}_i^G$ matrix) indicates 0.3 hours of remediation/regulatory overhead associated with atmospheric emissions. Hence the total value noted in Table 5 for atmospheric emissions employment hours is the product of these two terms, or 0.3 hours.

It is critical to emphasise that some values of the societal inventory (such as transport) are available, or known, others are calculated, as was shown with Eq. (2), and still others must be, indirectly, estimated. This combination between statistics and estimation is well accepted in economics, cost estimation and technical calculations. It could be that the field of societal life cycle assessment prefers to have elaborate inventories and render the employment inventory ($\mathbf{E}_{ij}$ matrix) geographically specific. The author does not believe this is either the most appropriate, nor the most expedient, means to carry out societal life cycle assessments, as the data collection effort balloons, though the option remains open.

An advantage of using employment hours as an intermediate variable in the societal life cycle assessment is that they are unambiguous and can be added (unlike the use, from the outset, of midpoint categories). Therefore, the $\mathbf{R}^{G,n}$ matrix of **Table 7** is rather simply calculated by summing the labour hours in the $\mathbf{H}_{kn}$ matrices (see Tables 5 and 6). It should be noted that the $\mathbf{R}^{G,n}$ matrix is not summarised across geographical regions. The reason for this was noted in a preceding section and relates to the fact that societal impacts have different magnitudes depending where the labour occurs. Therefore, to properly calculate the societal midpoints, one cannot aggregate geographically at an intermediate stage.

[2] As was discussed in Section 2.2, the employment which is estimated is not related to an eventual remediation itself, but rather to the tasks of monitoring (privately or publically) or in the case of significant emissions for point-source sequestration.

The methodology presented herein does not consider rebound effects. However, whereas in LCA where the liberation of free time can create additional environmental impacts, in Societal LCA extra free time has a positive influence on some social midpoint indicators. Specifically, the use of free time is what can be described as physical freedom. The simplest example of this would be the liberty to drive one's family to a picnic. It should be emphasized that the methodology for Societal LCA is developed for an indefinite number of midpoint categories. However, midpoints such as those describing physical freedom would be anticipated to be part of an ultimate list of indicators employed for Societal LCA, though the consensus on such a list would require political input.

Step 4: Characterisation table

The characterisation factors for societal life cycle assessment are summarized in the $\mathbf{C}_A{}^G$ matrix where 'A' the vector of Societal Impact Categories and 'G' the vector of Geographic Regions'. With a loose analogy to characterisation factors applied in LCA, the societal $\mathbf{C}_A{}^G$ matrix is a calculation (not an estimation) of the number of work hours a person requires to access various of the societal midpoint needs. This can be the number of employment hours to afford housing, access to health care (if state-provided then estimated via taxation and spending in the sector) as well as other variables, which can be in part subsidised, such as education. There have been over two hundred midpoint societal impacts proposed. For the purpose of illustration a short list of four have been selected for calculation. The extension to a larger list is not particularly difficult, provided the $\mathbf{C}_A{}^G$ matrix is calculated as it requires only the calculation of the person hour equivalents to access a societal impact midpoint in a given region.

Step 5: Characterisation results

The culmination of a societal life cycle assessment is the calculation, using Eq. (4) of the midpoint values for societal impact categories, the so named $\mathbf{S}_A{}^{G,n}$ matrix. This matrix, represented in Table 9, calculates the various mid-point societal impacts ($\mathbf{S}_A$) across the different geographical regions (G) for given product variants (n = 1 and 2 in the case of detergents). The calculation requires the employment matrices in Table 5 ($\mathbf{R}^{G,1}$) and Table 6 ($\mathbf{R}^{G,2}$) as well as the characterisation factors for societal life cycle assessment (the $\mathbf{C}_A{}^G$ matrix of **Table 8**). Clearly, the employment hours from the $\mathbf{R}^{G,n}$ matrices must be allocated to the various societal impact categories. This weighting is arbitrary, and we will no rekindle the debate linked to impact assessment in LCA. For the purpose of this calculation an egalitarian perspective has been selected, where each societal impact is weighted equally. Clearly, the establishment of the $\mathbf{C}_A{}^G$ matrix requires the regional prices for a given unit process. These are implicit in the calculation as an overall cost to access a given Societal midpoint is divided by the unit price to establish a number of labour hours required to satisfy this need.

Table 8: Characterization Factors (C_A^G Matrix with 'A' the vector of Societal Impact Categories and 'G' the vector of Geographic Regions')

Country	Average Wage (Euro/h)	Characterization Table (Work Hours/Unit)			
		Housing	Health Care	Education	Necessities
Germany	10	20000	600	300	50
Russia	2	50000	3000	250	250
France	8	25000	400	375	67.5
Canada	6	13000	1300	1000	80
South Africa	1	8000	2000	500	100
Morocco	0.5	160000	4000	1000	300
Switzerland	12	50000	750	400	70

One should note that the result is a table summarising the number of units of each societal impact which a given product provides. Therefore, for Detergent 1, the $\mathbf{S_A^{G,1}}$ matrix of **Table 9a** indicates that 0.000074 housing units could be obtained in Germany, with 0.00001 housing units in Russia, etc. While Table 9a and the $\mathbf{S_A^{G,1}}$ matrix show the geographical distribution, ultimately the number of housing units, as an example, can be summed across all regions. Therefore, Eq. (5) illustrates how the $\mathbf{S_A^1}$ vector is calculated by summing the values of a given societal impact, across regions. As an example, Detergent 1 generates access to 0.00011 housing units, whereas Detergent 2 provides 0.00012 housing units. Overall, Detergent 2 provides 109% of the housing units, 90% of the health care, 90% of the educational access and 93% of the access to necessities. The discussion of our learning from the application of this methodology to a screened case, and the case itself, will be presented in the following section.

B) Discussion of the Detergent Case Study

The case study demonstrates that Detergent 2 has, versus Detergent 1, approximately 20% less employment in Russia, 35% less in France, and approximately five times more in Canada and South Africa (see Table 7). There is essentially no difference in the employment in the use country (Switzerland) nor in Morocco, where some of the waste disposal was assumed to take place. Given that housing is more affordable, in terms of shelter units per labour hour, in Canada and South Africa, compared to Europe, it is, therefore, of no surprise that Detergent 2 provides a societal benefit in terms of housing (**Table 9b**). Detergent 2 does however result in dematerialization, in that its environmental impact is lower (LCI of Table 1 and Reference 7). Therefore, as less resources are employed and labour required, in extraction, production and transport, the societal benefits in health care, education and necessities, a grouped variable, are lower for Detergent 2 (see Tables 9a and 9b). This is despite the employment shift away from Europe and to less 'developed' regions. Clearly, any societal life cycle assessment methodology based on employment will face tradeoffs with environmental assessments tools if dematerialisation, often so important for the latter, results in reduced societal benefits. There are, of course, instances when this trade-off does not exist, and this relates to cases when the profit margin, which clearly has a very minimal impact on societal benefit, differs between two, comparative, products. This seems, the essence, of sustainability. A sustainable development requires consumers, producers, access to necessities, and an environment. Profit cannot be neglected, nor can it be optimised without consideration of environmental and societal variables. The contrary is also true in terms of the limits of societal benefit. It the methodologies that develop, perhaps in part as a result of this one, permit this, we have progressed quite far, indeed, en route to measuring, and hence moving towards, sustainability.

Table 9a: Outcome of the Societal life cycle assessment. Characterization Results for Detergent 1 ($S_A^{G,1}$ Matrix with 'A' the Vector of Societal Impact Categories, 'G' the Vector of Geographic Regions and the Index '1' Representing Detergent 1)

Characterization Results: Detergent 1				
Country	Housing (Units)	Health Care (Units)	Education (Units)	Necessities (Units)
Germany	0.000074	0.002459	0.004918	0.029505
Russia	0.000010	0.000158	0.001900	0.001900
France	0.000010	0.000625	0.000667	0.003704
Canada	0.000005	0.000050	0.000065	0.000813
South Africa	0.000005	0.000020	0.000080	0.000400
Morocco	0.000004	0.000175	0.000700	0.002333
Switzerland	0.000006	0.000370	0.000694	0.003964
Totals	0.00011	0.00386	0.00902	0.04262

Table 9b: Outcome of the Societal life cycle assessment. Characterization Results for Detergent 2 ($S_A^{G,2}$ Matrix with 'A' the Vector of Societal Impact Classes, 'G' the Vector of Geographic Regions and the Index '2' Representing Detergent 2)

Characterization Results: Detergent 2				
Country	**Housing (Units)**	**Health Care (Units)**	**Education (Units)**	**Necessities (Units)**
Germany	0.000052	0.001723	0.003445	0.020671
Russia	0.000008	0.000131	0.001574	0.001574
France	0.000007	0.000466	0.000497	0.002759
Canada	0.000025	0.000250	0.000325	0.004063
South Africa	0.000018	0.000070	0.000280	0.001400
Morocco	0.000005	0.000198	0.000791	0.002635
Switzerland	0.000009	0.000623	0.001169	0.006679
Totals	0.00012	0.00346	0.00808	0.03978
Totals as a Percent of Detergent 1	109%	90%	90%	93%

C) Assumptions Made in the Case

The calculation of the labour hours was obtained from the selling price after the profit margin had been deducted. As an example, if energy cost 0.1 Euro per kWh in Germany, as an example, and the margin on this was 5%, the effective economic value of the energy used to correlate to labour statistics was 0.095 Euro/kWh. The data in Tables 2, 3 and 4 are estimates, with various degrees of precisions. However, other than the data quality issue, or imprecision, there are no assumptions in the labour statistics quoted.

D) Sensitivity Analysis

A sensitivity analysis has been carried out, relative to the base LCI and labour data in Tables 1 and 2, respectively. This indicates that housing is most influenced by the aluminium metal resource. This is quite reasonable as a fraction of the aluminium required in the detergents were assumed to be derived from South Africa and the country's last two Presidents have provided quality shelter for over 40% of the nations families at a cost of Euro 8000/unit. Clearly, any product substitution which generates employment in South Africa will have a positive effect on housing as a societal variable. Moreover, the extent of this dependence is very strong (the societal metric for housing doubles for every tenfold increase in labour hours in South Africa) given the low cost of housing in South Africa.

Education is most influenced by fossil fuel use and health care by electricity, though both dependencies are modest, changing only by 30 and 20%, respectively, for four-fold modifications to the LCI/labour statistics. The direction of the relationships is, however, worth noting. Fossil fuel use moves employment East, to the former Soviet states, for which the indirect cost of education, expressed in labour hours, remains low (see Table 8), compared to Europe or any former non-planned countries. As part of the electricity for production in Germany is assumed to be imported from France, and health care is relatively inexpensive in France, the link, though modest, is clearly established.

Access to necessities was most influenced by aqueous emissions, though the relationship was very minor, with a 10% change in educational access linked to a 400% change in COD. Therefore, one can conclude that education, as a societal metric, is not particularly influenced by the substitution of one detergent for the other.

Atmospheric emissions, heavy metals and COD are relatively insensitive in terms of their impact on the four societal variables investigated. This is intellectually satisfying as societal life cycle assessment and LCA are relatively orthogonal, and double counting seems minimised. Only solid waste had a significant effect on a societal variable and even so, a 400% increase in solid waste resulted in less than a 15% change in access to education, so the dependency is very limited indeed.

Overall, the results of the societal life cycle assessment, comparing two detergents, do not demonstrate extensive differences, though rather fascinating trends are observed. The fact that we see societal benefits linked not only to the inventory, but also the political history of a region is an outcome of the method, as clearly societal life cycle assessment is providing perspective. Furthermore, the trans-border cooperation between firms, as well as policy decisions linked to, for example, the energy mix and transport conditions, provides us some confidence that the method covers most of what we would seek from a assessment tool. Indeed, it orients us not merely tradeoffs, as we would have anticipated from the outset, but rather it provides some quite unexpected insight into how our products influence our social well-being. Therefore, perhaps with sustainability assessment, one benefit will not be to see the tradeoffs between environment and society, as an example, but to understand how a given product can improve access to housing and reduce health care availability. Societal assessment can, it seems, provide a macro-economically based tool which has some of the advantages of detailed analyses and a basis for, rather sophisticated, multi-stakeholder discussions.